Reprint **ISSN 1991-3036 (Web Version)**

International Journal of Sustainable Crop Production (IJSCP)

(***Int. J. Sustain. Crop Prod.***)

Volume: 7 **Issue: 2** **May 2012**

Int. J. Sustain. Crop Prod. 7(2): 1-8 (May 2012)

EFFECT OF ARSENIC ON THE NUTRITIONAL QUALITY OF BARANUNIYA (*PORTULACA OLERACEA* L.)- A WEED VEGETABLE

M.R. SHAIBUR, T. ISLAM, N. NAHAR, N. JAHAN AND N. ARA

GGF
Nature is Power

An International Scientific Research Publisher
Green Global Foundation©
Publication and Bibliography Division
100 Leeward Glenway
Apartment # 1601
M3c2z1, Toronto, Canada
E-mails: publication@ggfagro.com, editor@ggfagro.com
http://ggfagro.com/ejournals/current issues

IJSCP** issn 1991-3036, HQ:19-10 cantral place, saskatoon, saskatchewan, s7n 2s2, Canada

ISSN-1991-3036 (Online)
Int. J. Sustain. Crop Prod. 7(2): 1-8 (May 2012)

EFFECT OF ARSENIC ON THE NUTRITIONAL QUALITY OF BARANUNIYA (*PORTULACA OLERACEA* L.)- A WEED VEGETABLE

M.R. SHAIBUR*[1], T. ISLAM[2], N. NAHAR[3], N. JAHAN[4] AND N. ARA[5]

[1,3]Department of Environmental Science & Health Management, Jessore Science & Technology University, Jessore 7408, Bangladesh
[2]Department of Agro-bioscience, Faculty of Agriculture, Iwate University, Morioka 020-8550, Japan; [4]Biotechnology and Genetic Engineering Department, University of Development Alternative, Dhanmondi, Dhaka 1209, Bangladesh; [5]Pharmacy Department,University of Development Alternative, Dhanmondi, Dhaka 1209, Bangladesh.

Corresponding author & address: Molla Rahman Shaibur, *E-mail: shaibur75@yahoo.com

Accepted for publication on 11 March 2012

ABSTRACT

Shaibur MR, Islam T, Nahar N, Jahan N, Ara N (2012) Effect of arsenic on the nutritional quality of baranuniya (*Portulaca oleracea* L.)- a weed vegetable. *Int. J. Sustain. Crop Prod.* 7(2), 1-8.

The hydroponic baranuniya (*Portulaca oleracea* L.) was treated with arsenic (As) at the rate of 0, 10, 25 and 50 μM in the greenhouse to investigate the effect of As on its mineral nutrient composition. The plants were harvested on 14 days after treatments (DAT). The leaves and stems were separated from the plant parts. Arsenic limited the concentration of phosphorus (P) at 50 μM level in the leaves and roots, but, P concentration enhanced in stems. Potassium (K) concentration was not affected in leaves, but, enhanced in stems and roots at 25 and 50 μM As levels. Calcium (Ca) concentration enhanced in roots with the applied As. Magnesium (Mg) concentration limited in leaves and stems at 10, 25 and 50 μM As levels. Iron (Fe), manganese (Mn) and zinc (Zn) concentrations augmented in all parts at 25 and 50 μM As levels, but, copper (Cu) concentration augmented only in roots along with As levels. An accumulation of Fe seems to be enhanced marginally in the stems. Manganese, Zn and Cu accumulations limited in leaves at 50 μM As level. Most of the cases, As limited the accumulations of nutrient elements in leaves, stems and roots, which was expected due to the reduction of dry weight (DW). Translocation of P, K, Ca, Mg and Mn seems to be not affected much by As treatments. Translocation of Zn and Cu limited in 50 μM As level, however, Fe translocation enhanced in some cases with the applied As. The result indicated that As showed its toxicity by hampering the nutrients balance in the plant tissues by changing mostly the concentrations and accumulations.

Key words: *accumulation, arsenic, concentration, mineral nutrition, suberihiyu, translocation*

INTRODUCTION

The toxic metalloid arsenic (As) is widely distributed in nature e.g.- in soil, water, air, plant, animal and human body (Mandal and Suzuki, 2002). On the basis of abundance, As is ranked 20th in the earth crust, 14th in the seawater and 12th in the human body (Mandal and Suzuki, 2002). Generally, the background As levels in top soils are low (Kabata-Pendias 2001). Groundwater contains As but its source has not been clearly identified yet. Some researchers have reported that groundwater contamination with As is attributed to the anthropogenic sources (Anawar *et al.* 2002). On soils, where As contaminated irrigation water is being widely used may have high concentrations of As (Imamul Huq *et al.* 2003; Meharg and Rahman, 2003) and reducing the crop production. Arsenic phytotoxicity depends mainly upon which chemical form is present, with the arsenite being more toxic than the arsenate, whereas, both of these are more toxic than the organic As compounds (Sachs and Michael, 1971). Arsenic toxicity changes the concentration, accumulation and translocation of nutrient elements in plant tissues (Shaibur *et al.* 2006; Shaibur *et al.* 2008; Shaibur and Kawai, 2011a, b). Concentration or content, uptake or accumulation or absorption or total content, translocation or transfer factor (TF) is widely used terminologies in the field of plant nutrition. Generally, concentration is defined as the amount of a substance in a liquid or in another substance (Hornby 2000). Accumulation could be defined as "the process of increasing the number or quantity of something" (Hornby 2000). In plant science, concentration refers to the unit amount of the specific element in a unit amount of samples, whereas accumulation or uptake or total amount or total content or absorption refers to the total amount of the element in shoot or root of a plant (Shaibur *et al.* 2008; Shaibur *et al.* 2009).

In some cases, the terminologies concentration and accumulation or acquiring or uptake are used to indicate same term (Gahoonia *et al.* 2006; Tu *et al.* 2002). Artus (2006) used the concentration unit (mg As kg^{-1} DW; dry weight) but, used the terminology as accumulation. Concentration is being used as mg of element g^{-1} DW/FW (fresh weight) and μg of element g^{-1} DW/FW (Imamul Huq *et al.* 2005, Shaibur and Kawai, 2009; Shaibur and Kawai, 2010). Therefore, it is necessary to know if there is any difference among concentration, content, accumulation, uptake, total content, absorption, translocation or transfer factor, because, the individual terminology has its own meaning and unit. Translocation is the process of transferring of an element from root to the shoots. The translocation is mostly related to the accumulation or uptake in agriculture (Shaibur *et al.* 2007). Translocation factor or TF is used to identify if a plant is hyperaccumulator or not.

Many weed vegetables are grown in the countryside of Bangladesh. Baranuniya (*Portulaca oleracea* L.) is one of them. Baranuniya or Baralaniya is called as Suberihiyu in Japanese. It is collected frequently as pokeweed and Amaranthus pigweed. It is the common annual weed in Bangladesh and Japan, mostly grown in summer. In English, it is called as summer purslane. Sometimes it is also called as pigweed, little hogweed, postelijn, pourpier, portulat, garden purslane or fatweed as its leaves and stems are very fleshy and succulent. Its family is portulacaceae. The stems are reddish and the fleshy succulent leaves alternate, while the small flowers are yellow. Its smooth purplish red prostrate stems arising from a single taproot. Baranunia is used as popular edible vegetable in Bangladesh including other Asian and European countries. It contains vitamins A, C and E and the minerals- phosphorus (P), potassium (K), calcium (Ca), iron (Fe; high level), manganese (Mn), copper (Cu) and silicon (Si). Protein content is about 2 to 2.5% (TROPILAB^{R}INC, 2006; available at: http://www.tropilab.com/purslanetincture.html). Purslane (Baranuniya) derives from the Latin "portulacca" and the old French "pourcelaine". It is not clear from where it was introduced to Bangladesh and Japan, but it is the most abundant in both the countries. Whole young plants and young leaves can be eaten as raw salads and the taste is similar to watercress or spinach. It is also used as the feed of cattle and goat. In Japan, about 20 verities of Baranuniya were found so far, but only Suberihiyu is widely distributed but in Bangladesh the species number is not clear. The nutritional quality of higher plants is hampered by the toxic substances, especially As. Reports show that As hampered the nutritional quality of different crops e.g.- rice (Shaibur *et al.* 2006; Shaibur *et al.* 2008; Shaibur and Kawai, 2011a, b), Kalmi (Shaibur *et al.* 2009) and Spinach (Shaibur and Kawai, 2009; Shaibur and Kawai, 2010). It is therefore necessary to investigate if there is any change of nutrients in Baranuniya or not by the higher concentrations of As. Baranuniya is widely grown as weed vegetable in the agricultural field and the field is often irrigated with As contaminated water. The main objective was to observe the effect of As-toxicity on the concentration, accumulation and translocation of the nutrient elements in As stressed Baranuniya.

MATERIALS AND METHODS

Seedling collection and sample preparation

Baranuniya seedlings were collected from the Botanical garden of Iwate University, Morioka, Japan, on 16 August, 2006 and were transferred to 10-l opaque plastic PVC bucket, containing half-strength nutrient solution (Hoagland and Arnon, 1950) in the greenhouse for 8 days and allowed to acclimate to the natural environmental condition of the greenhouse. The seedlings were wrapped with sponge rubber and were suspended through the holes of the plastic lid cover put over the bucket of the nutrient solution. After the acclimation period, the seedlings were sufficiently healthy for starting the As treatments. The full-strength modified nutrient solution contained 6.0 mM KNO_3; 4.0 mM $Ca(NO_3)_2$; 1.0 mM $NH_4H_2PO_4$; 2.0 mM $MgSO_4$; 20.0 μM Fe(III)-EDTA (Ferric-monosodium Ethylene Diamine Tetraacetic acid, $C_{10}H_{12}N_2O_8NaFe.3H_2O$), 3 μM H_3BO_3; 0.5 μM $MnSO_4$; 0.2 μM $CuSO_4$; 0.4 μM $ZnSO_4$ and 0.05 μM H_2MoO_4. The pH of the nutrient solution was not adjusted during the acclimation period. Four (4) more or less uniform seedlings were taken in each bucket and allowed to grow. We did not have any chance to understand the real age of the seedlings, because, the seedlings were randomly collected from the garden. After 8 days of acclimation, plants were subjected to the different As treatments. Arsenic (certificate of analysis) was added as sodium meta-arsenite ($NaAsO_2$; Kanto Chemical Company, Tokyo, Japan). The nutrient solution was renewed every week and was aerated continuously with the aquarium pumps and air stone aerator during the experiment. The pH (pH 5.5) of the nutrient solution was adjusted daily with a digital pH meter (Horiba Korea, Seoul, Korea) and with 1 M HCl and/or 1 M NaOH at around 16 hours during the experiment (August-September 2006). The temperature of the greenhouse was around 32ºC in the day and 20ºC at night, respectively. During the experiment, the days were almost sunny and the night was clear.

Treatments of arsenic and reagents

After acclimation in the greenhouse, the seedlings were treated with 0, 10, 25 and 50 μM As. The duration of the As treatments was 14 days. All chemicals used were of analytical reagent grade. All solutions were prepared previously with MQ water (18.2 MΩ cm^{-1}), purified by Milli-RO 60 (Millipore Corporation, USA) and stored in the laboratory in room temperature. Stock solution of As was prepared by dissolving $NaAsO_2$ in MQ water.

Analysis of plant samples

Among the seedlings, 3 representative seedlings were chosen from each treatment. The seedlings were harvested on 14 DAT (days after treatments), washed with tap water first and followed by 3 rinses with deionized water. Leaves were separated by clean hands but stems and roots were separated with stainless steel razor and put them separately into paper packet (new and clean) and dried at 55˚C for 48 hours in the electric oven (Isuzu Seisakusho Company, Tokyo, Japan). The oven dried samples were weighted and digested with a nitric acid-perchloric acid mixture ((5:1 = V/V; Piper 1942). The volume of the digested solution was made at 50 mL with MQ water. The amount of K, Ca, Mg, Fe, Mn, Zn and Cu were determined by Atomic Absorption Spectroscopy (170-30 Atomic Absorption Spectrophotometer; Hitachi Ltd., Tokyo, Japan). Phosphorus was determined colorimetrically using a UV-visible Spectrophotometer (model UV mini 1240, UV-Vis Spectrophotometer; Shimadzu Corporation, Kyoto, Japan) at 420 nm wavelengths after developing the yellow color with vanadomolybdate as described by Barton (1948) and Jackson (1958).

Calculation for the parameters

Concentration in mg or μg of element g^{-1} DW; accumulation in shoot in mg or μg of element plant^{-1} shoot; accumulation in root in mg or μg of element plant^{-1} root; and translocation (%) in nutrient accumulation in shoot (stem + leaves)/total accumulation (shoot + root) × 100 (Shaibur *et al.* 2006).

Statistical analysis

The experiment was arranged in randomized blocks with three replications. Data of mineral nutrients of leaves, stems and roots were subjected to ANOVA. Differences between means were evaluated using a Ryan-Einot-Gabriel-Welsch multiple range test (P = 0.05) using computer origin 5 at Iwate University, Morioka 020-8550, Japan. The results were expressed as mean values of measurements with replications ± standard deviation (SD).

RESULTS AND DISCUSSION

Dry weight

Dry weight as represented by leaf, stem and root was decreased by the application of As (data not shown). This was certainly due to the toxic effect of As on growth reduction. It was also reported that the DW of shoot and root; and leaf area of rice seedlings limited significantly at the 0.8 and 1.6 mg As l^{-1} rates of DMAA (Dimethyl arsenic acid; Marin *et al.* 1993). Dry weight of shoots and roots of hydroponic rice was also reduced by As at the rate of 6.7, 13.4 and 26.8 μM, used as $NaAsO_2$ (Shaibur *et al.* 2006).

Table 1. Concentration of macro-elements in leaf, stem and root of Baranuniya grown hydroponically with different levels of As

Treatment (μM)	P (mg g^{-1} DW)			K (mg g^{-1} DW)			Ca (mg g^{-1} DW)			Mg (mg g^{-1} DW)		
	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
0	10.35a	2.66c	3.64a	112.5ab	103.8b	26.32b	14.15a	9.73a	4.39c	9.35a	4.26a	2.27a
10	12.42a	4.11b	2.70b	116.7ab	126.1a	25.48b	9.69b	6.67b	5.77b	5.13bc	2.36b	2.02a
25	11.61a	5.17a	2.77b	126.4a	129.7a	36.13a	10.21b	5.42bc	5.81b	6.01b	2.64b	2.52a
50	9.02b	5.21a	2.10b	124.6a	134.3a	37.08a	8.02c	4.69c	6.44a	4.75c	2.19b	2.03a

[a] Means followed by the different letters in each column are significantly different (p= 0.05) according to Ryan-Einot-Gabriel-Welsch multiple range test. DW = dry weight

Table 2. Concentration of metal-microelements in leaf, stem and root of Baranuniya grown hydroponically with different levels of As

Treatment (μM)	Fe (μg g^{-1} DW)			Mn (μg g^{-1} DW)			Zn (μg g^{-1} DW)			Cu (μg g^{-1} DW)		
	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
0	75.33c	16.97d	333.9c	11.92c	8.80d	5.01b	11.82c	5.31d	11.79d	5.52a	4.02a	15.34c
10	159.7b	56.06c	265.1d	14.58b	11.55c	6.57b	11.59c	8.05c	22.91c	4.94a	3.45ab	18.34bc
25	161.2b	74.85b	782.7a	20.51a	19.65a	9.99a	23.13a	18.40a	28.24b	4.94a	3.55ab	20.40b
50	235.5a	85.35a	675.8b	17.69a	17.05a	10.65a	17.74b	13.42b	38.02a	4.65a	4.79a	60.53a

[a] Means followed by the different letters in each column are significantly different (p= 0.05) according to Ryan-Einot-Gabriel-Welsch multiple range test. DW = dry weight

Table 3. Translocation (%) of elements from roots to the aerial parts (stem plus leaf) of Baranuniya seedlings grown hydroponically with different levels of As

Treatment (μM)	P	K	Ca	Mg	Fe	Mn	Zn	Cu
0	95.37a	98.25a	97.24a	97.36a	60.92c	96.46a	89.99a	80.39a
10	96.70a	98.09a	93.57ab	94.82a	79.61a	95.25a	81.47b	70.24b
25	96.90a	97.51a	93.39ab	94.65a	61.05c	95.57a	88.81a	69.16b
50	97.31a	97.61a	91.23ab	94.54a	69.71b	95.02a	81.99b	47.42c

[a] Means followed by the different letters in each column are significantly different (p= 0.05) according to Ryan-Einot-Gabriel-Welsch multiple range test. Translocation (%) was expressed in nutrient accumulation in shoot (stem + leaves)/total accumulation (shoot + root) × 100 (Shaibur *et al.* 2006)

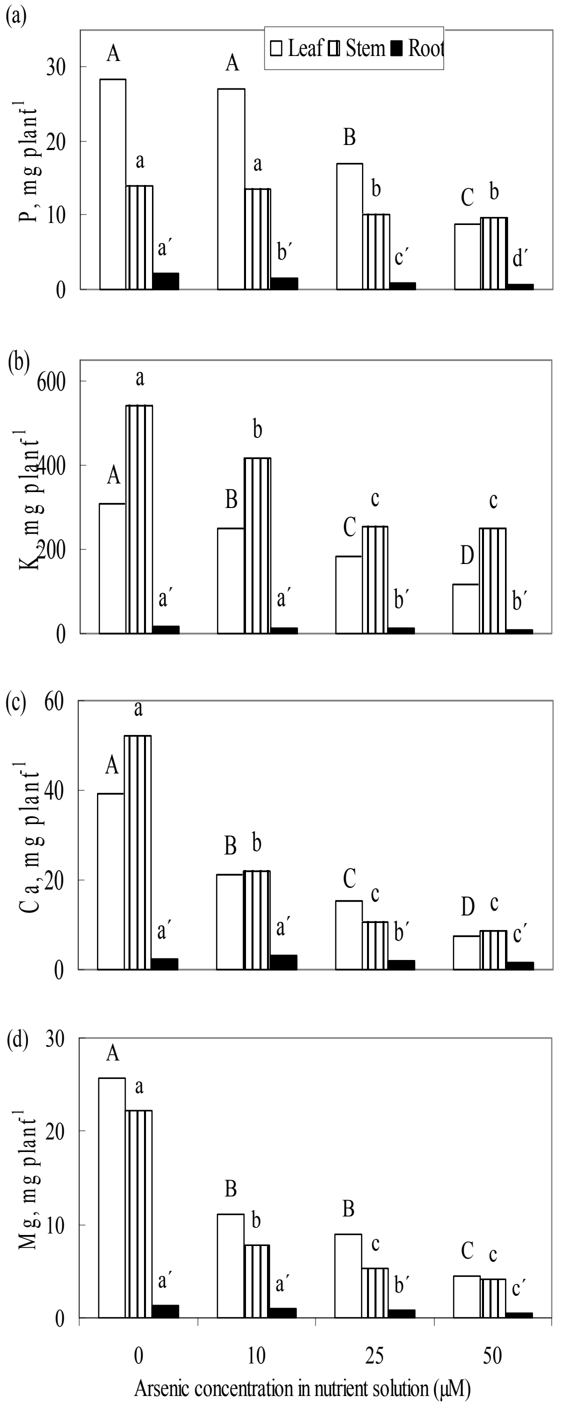

Fig. 1. Effect of As on the accumulation of (a) P, (b) K, (c) Ca and (d) Mg in leaf, stem and roots of Baranuniya. Bars with the different letters of same group are significantly different ($p<0.05$) according to Ryan-Einot-Gabriel-Welsch multiple range test

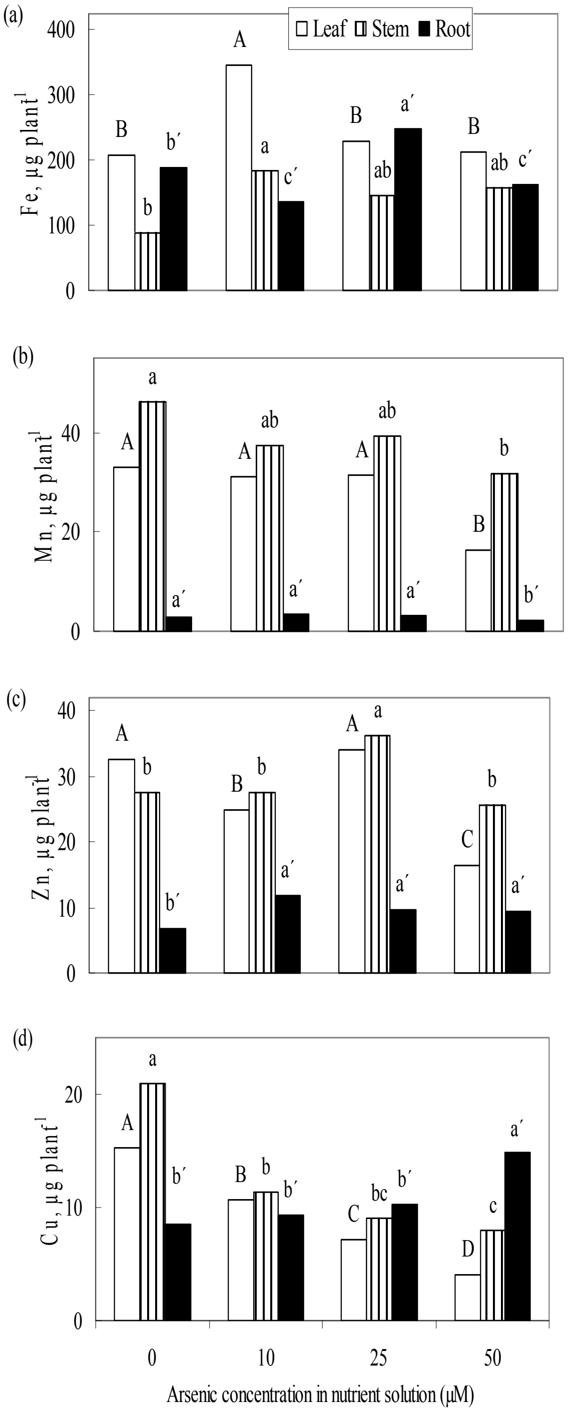

Fig. 2. Effect of As on the accumulation of (a) Fe, (b) Mn, (c) Zn and (d) Cu in leaf, stem, and roots of Baranuniya. Bars with the different letters of same group are significantly different ($p<0.05$) according to Ryan-Einot-Gabriel-Welsch multiple range test

Effect of As on P

Phosphorus is the only non-metal that we measured for this experiment. In control treatment, P concentrations were 10.35, 2.66 and 3.64 mg g^{-1} DW in leaf, stem and root, respectively (Table 1), indicating that the leaf of Baranuniya contained higher concentrations of P. Typical P concentrations in common plants are 2-4 mg g^{-1} DW (Liao *et al*. 2004) or 3-4 mg g^{-1} DW (Mengel and Kirkby, 2001) during the vegetative growth stage. In this experiment, As toxicity decreased P concentration significantly in leaves at 50 µM level as compared to control.

Similar results were also recorded at 10, 25 and 50 µM As levels in roots, however, the concentration enhanced significantly in stem with increasing As concentrations in the nutrient solution (Table 1). The reduction of P concentration (in leaves and roots) was not the effect of dilution, because, the growth as well accumulation (Fig. 1a) were limited much with the As toxicity. Arsenic is chemically similar to P, therefore, it is likely to take part in many reactions in the plant cells. Specific organic As compounds e.g.- arsenobetaine, arsenocholine or arsenolipids have been found in some organisms. Arsenic replaces the P in the phosphate groups of DNA has been reported (Lepp 1981). We reported that P concentration was enhanced in the shoots but reduced in roots of hydroponic rice by As (Shaibur and Kawai, 2011a). In this present experiment, P accumulation decreased in leaves, stems and roots with increasing As in the medium (Fig. 1a). Most of the P was accumulated in leaves and the second highest was in the stems (Fig. 1a). No significant change of P translocation was observed in our experiment, suggesting that after absorption As might not compete with P through the xylem tube when arsenite was used in the solution. This supposition needs to be verified.

Effect of As on K

Potassium is the monovalent cation that is essential for plant growth. In control plants, K concentrations were 112.54, 103.84 and 26.32 mg g^{-1} DW in leaf, stem and root, respectively (Table 1). This concentration of K seems to be relatively high. This is probably owing to the plants high demand for this element at this stage. Potassium concentrations as high as 100 to 140 mg g^{-1} DW can occur in hydroponically grown plants (Leigh and Wyn-Jones, 1984; Wheeler *et al.* 1994). In this experiment, K concentration was not affected much in leaf by the As toxicity (Table 1). However, enhanced in stem at 10, 25 and 50; and in root at 25 and 50 µM As levels (Table 1). The enhancement of K concentration might be the concentration effect as the growth and accumulation were limited (Fig. 1b) with the As toxicity. It is known that K is a cation for anions (Clarkson and Hanson, 1980), therefore, part of synergistic relationship between As and K might be possible in stems and roots due to the necessity of keeping electronutrality or ionic balance. Arsenic is taken up as anion (arsenite or arsenate) and K is taken up as K^+, therefore, there is almost no possibility to show antagonistic relationship, but, they showed antagonistic relationship in some cases (Shaibur and Kawai, 2011a, b), assuming a toxic effect of As on K absorption. In the present experiment, K accumulation was limited in leaf with the increasing As (Fig. 1b). Similar results were also obtained in stem and root. The highest amount of K was accumulated in stems and the lowest K was accumulated in roots. We did not find the significant effect of As on K translocation from root to the aerial parts.

Effect of As on Ca

The Ca concentration in plants varies between 0.1 and >5% of DW depending on the growing conditions, plant species and plant organ (Marschner 1998). The experimental plants contained 1.42, 0.97 and 0.44% Ca (DW) in leaf, stem and root of control plants, respectively (from Table 1). Controlled plants contained 14.2, 9.73 and 4.39 mg Ca g^{-1} DW in leaf, stem and root, respectively (Table 1). These data suggest that Baranuniya might contain higher concentration of Ca. In this experiment, As toxicity decreased Ca concentration significantly in leaf and stem in the 10, 25 and 50 µM levels, however, the concentration enhanced in root for the same As treatments as compared to control (Table 1). Calcium was mostly concentrated in leaf and stem; and little amount was concentrated in root of control plants. In this present experiment, not only concentration but also accumulation was limited much in all the plant parts with increasing As (Fig. 1c). Arsenic decreased the Ca concentration is the xylem sap of barley was reported recently (Shaibur *et al.* 2012). In the present experiment the highest accumulation was recorded in the control plants and the lowest was in 50 µM As treated plants. Calcium was mostly accumulated in the stem of control plant. It was observed that the translocation of Ca was also negatively affected by the applied As. Translocation of Ca reduced from 97% to 91% in 50 µM As level.

Effect of As on Mg

In leaf tissues, the threshold value for the occurrence of deficiency symptoms is in the region of about 2 mg Mg g^{-1} DW (Mengel and Kirkby, 2001). Our control plants contained 9.35, 4.26 and 2.27 mg Mg g^{-1} DW in leaf, stem and roots, indicating that the value is over the CDL (critical deficient level) of Mg. The Mg requirement for optimum plant growth is in the range of 0.15 to 0.35% DW of the vegetative parts (Marschner 1998). The experimental plants contained 0.94, 0.43 and 0.23% (DW) of Mg in leaf, stem and root, respectively, indicating that the higher level than the normal in leaf and stem. We found, As toxicity significantly decreased Mg concentration in leaf and stem; and no change was in the root with increasing As (Table 1). The reduction of Mg concentration was the toxic effect of As on the nutrient balance. We found that As toxicity limited Mg accumulation in Baranuniya (Fig. 1d). Most of the Mg was accumulated in leaf and the lowest was accumulated in root. In this present experiment, As toxicity did not limit Mg translocation from root to the aerial parts.

Effect of As on Fe

The control plants contained 75.33, 16.97 and 333.87 µg Fe g^{-1} DW in leaf, stem and root, respectively (Table 2). Concentration of Fe in the green tissues is low in comparison with the macro nutrients and generally in the order of 50-100 µg Fe g^{-1} DW (Mengel and Kirkby, 2001). However, the CTL (critical toxicity level) is above

500 µg Fe g^{-1} DW of leaf (Marschner 1998). Therefore, the leaf of our experimental plants contained normal concentration of Fe. In this experiment, Fe concentration enhanced in leaf and stem in all treatments of As (Table 2) and this situation might be compensated especially in leaf by reducing the concentrations of Ca, Mg and Cu to keep the charge equilibria or electronutrality. The enhancement of Fe concentration was taken place in root at 25 and 50 µM As levels (Table 2). Wallace *et al.* (1980) reported that, Fe concentration enhanced in leaves, stems and roots of bush bean plants (*Phaseolus vulgaris* L. cv. Improved Tendergreen) at 10^{-4} M As level, though, the plants were treated with 0, 10^{-6}, 10^{-5} and 10^{-4} M $H_2AsO_4^-$. In this present experiment, Fe accumulation in leaf was not affected much with As treatments (Fig. 2a). Similar results were also obtained in stems and roots. In the highest As concentration, the accumulation decreased in roots certainly due to the growth reduction. Iron translocation was not affected by the As treatments used in this hydroponic experiment (Table 3).

Effect of As on Mn

The CDL of Mn in plants are similar for most plant species is in the range of 10-20 µg Mn g^{-1} DW of mature leaves (Marschner 1998; Mengel and Kirkby, 2001). Based on this value, the Mn concentration in leaf of the control plants was within the CDL (Table 2). Arsenic toxicity augmented Mn concentration in leaf and stem at 10, 25 and 50 µM levels (Table 2). Similar results were also obtained in root at 25 and 50 µM As levels. This might be the concentration effect, because, the growth decreased with the increasing As. Wallace *et al.* (1980) reported that As at 10^{-4} M level reduced Mn concentration in leaves, but, enhanced in stems of bush bean plants grown hydroponically. It was also reported that, Mn concentration in shoot and in root of rice was not affect by the applied DMAA in hydroponic rice (Marin *et al.* 1993). Our data showed that Mn accumulation limited significantly in all the plant parts in the highest As level (Fig. 2b). No effect of As toxicity on Mn translocation was recorded (Table 3), suggesting that As may not compete with Mn during the translocation through the translocation site in Baranuniya.

Effect of As on Zn

The control plants contained 11.82, 5.31 and 11.79 µg Zn g^{-1} DW in leaf, stem and root, respectively (Table 2). For most plant species Zn concentrations in leaves below 10-15 µg g^{-1} DW are indicative of Zn deficiency and 20-100 µg g^{-1} DW are sufficient (Boehle and Lindsay, 1969; Mengel and Kirkby, 2001). Generally, Zn concentrations in the order of 150-200 µg g^{-1} DW of plant tissue are considered as toxic (Sauerbeck 1982; Mengel and Kirkby, 2001). Therefore, the control plants of the present experiment are Zn deficient. Zinc concentration enhanced in the leaves at 25 and 50 µM As levels as compared to control. Similar results were also obtained in stem and root for all the applied As levels (Table 2). This might be the concentration effect as the growth limited with increasing As. Reduction of Zn concentration in shoots of As treated hydroponic rice was also reported (Shaibur *et al.* 2006). These differences were most probably due to variation of plant species, experimental set up and the environmental conditions. In this experiment, As toxicity limited Zn accumulation in leaf and stem at 50 µM level (Fig. 2c). However, the opposite result was obtained in roots with the increasing As in the solution, resulting in the lowest translocation in the highest As level (Table 3). In this experiment, Zn translocation decreased from 90% to 82% at 50 µM As level (Table 3). The marked differences of the concentration and accumulation of different nutrient elements may be related to the sensitivity of these elements to the As toxicity.

Effect of As on Cu

The concentrations of Cu in leaf, stem and root of control plants were 5.52, 4.02 and 15.3 µg Cu g^{-1} DW, respectively (Table 2). The CDL level of Cu in vegetative plant parts is generally in the range of 1-5 µg g^{-1} DW depending on the plant species, plant organ, developmental stage and nitrogen supply (Thiel and Finck, 1973; Robson and Reuter 1981). For most crop species, the CTL of Cu in the leaves is above 20-30 µg g^{-1} DW (Hodenberg and Finck, 1975; Robson and Reuter, 1981). Therefore, the normal concentration of Cu in leaf tissues is 5–20 µg g^{-1} DW. In this experiment, the Cu concentration in leaves of As treated plants were within the deficient level, ranging from 4.94–4.65 µg g^{-1} DW (Table 2). It means, the leaves of control plants contained normal concentration of Cu. Arsenic toxicity did not affect the Cu concentration significantly both in leaf and stem, however, the concentration enhanced in root in all the applied As treatments (Table 2). The accumulation of Cu was reduced in leaf and stem, however, enhanced in root with the increasing As (Fig. 2d). This might be due to the fact that, in presence of As, Cu could not be easily translocated from roots to the shoots (Table 3), resulting in higher accumulation in the roots. We found that Cu translocation limited from 80% to 70, 69 and 47%, respectively at 10, 25 and 50 µM As levels (Table 3). The function of Cu is thought to be related to the activity of enzymes e.g.- phenolase and laccase (Carbonell-Barrachina *et al.* 1994). In Cu deficient tissues, phenolase activity is lowered and an accumulation of phenols occurs (Robson *et al.* 1981). The decrease in lignification can cause the xylem vessels to collapse and consequently the transport of water is blocked, resulting in lower amount nutrient uptake from solution (Carbonell-Barrachina *et al.* 1994).

CONCLUSION

Leaf contains higher concentration of P, K, Ca and Mg as compared to other parts of Baranuniya. However, the concentrations of metal micronutrients in control plants were normal level or within the CDL, suggesting that Baranuniya may be a good source of P, K, Ca and Mg.

Arsenic decreased the concentration of P, Ca and Mg in shoots, however, in some cases; the concentration increased e.g. K, Fe, Mn and Zn. Most of the cases accumulation data (without Fe) showed a general reduction of the elements in leaf, stem and root with increasing As, which was expected due to the reduction of DW. Our result indicated that, As showed its toxicity by hampering the nutrient balance in plant tissues and reduced the quality of the vegetable. The translocations of P, K, Ca, Mg and Mn were not much affected, indicating that upon absorption, arsenic might not compete with P, K, Ca, Mg and Mn through the translocation site in Baranuniya. Among the metal micronutrients, the translocation of Cu decreased much as compared to the others. The reduction in the translocation of Cu towards the aerial parts of the plant might be related to the structural damage of the root caused by As toxicity. Limited study conducted on weed crops, showed a wide variation in the concentrations, accumulations and translocations of the different nutrient elements. A more detailed study is needed to asses the potential role of As toxicity in the transfer of nutrient element from root to the aerial parts. This hydroponic experiment has revealed that an increase of As concentration in the rooting medium leads to an increase of its phytotoxicity. Finally, it could be said that As hampers the nutritional quality of the weed vegetable Baranuniya by hampering the concentrations and accumulations.

REFERENCES

Anawar HM, Akai J, Mostofa KMG, Saifiullah S, Tareq SM (2002) Arsenic poisoning in groundwater: Health risk and geochemical sources in Bangladesh. *Environment International*. 27, 597-604.

Artus NC (2006) Arsenic and cadmium phytoextraction potential of Crambe compared with Indian mustard. *Journal of Plant Nutrition*. 29(4), 667-679.

Barton CJ (1948) Photometric analysis of phosphate rock. *Analytical Chemistry*. 20(11), 1068-1073.

Boehle J, Lindsay WL (1969) Micronutrients. The Fertilizer Shoe-Nails. Pt. 6. In the Limelight-Zinc. *Fertilizer Solutions*. 13(1), 6-12.

Carbonell-Barrachina A, Burló-Carbonell F, Mataix-Beneyto J (1994) Effect of arsenite on the concentrations of micronutrients in tomato plants grown in hydroponic culture. *Journal of Plant Nutrition*. 17(11), 1887-1903.

Clarkson DT, Hanson JB (1980) The mineral nutrition of higher plants. *Annual Review of Plant Physiology*. 31, 239-298.

Gahoonia TS, Ali O, Sarker A, Nielsenand NE, Rahman MM (2006) Genetic variation in root traits and nutrient acquisition of lentil genotypes. *Journal of Plant Nutrition*. 29(4), 643-655.

Hoagland DR, Arnon DI (1950) The water culture method of growing plants without soil. *California Agricultural Experiment Station, University of California, Circular 347*. Berkeley.

Hodenberg A von, Finck A (1975) Ermittlung von toxizitäts-grenzwerten für zink, kupfer und blei in hafer und rotklee. *Z. Planzenernähr, Bodenk.* 138, 489-503.

Hornby AS (2000) Oxford advanced learner's dictionary of current English. 5th edition. Ed J Crowther. Oxford University Press. New Delhi.

Imamul Huq SM, Alam S, Kawai S (2003) Arsenic in Bangladesh environment and its impact on food chain through crop transfer. Abstract No. 22-45. Abstract of the Annual Meeting, Japanese Society of Soil Science and Plant Nutrition. Vol 49. Held in Meiji University, Tokyo, August 20-22, 2003. pp. 177.

Imamul Huq SM, Joardar JC, Parvin S (2005) Marigold (*Tagetes patula*) and ornamental arum (*Syngonia* sp.) as phytoremediators for arsenic in pot soil. *Bangladesh Journal of Botany*. 34(2), 65-70.

Jackson ML (1958) Total elemental phosphorus. In: Soil Chemical Analysis. Ed. M. L., Jackson. Prentice-Hall, Englewood Cliffs, New Jersey, USA. pp.175-176.

Kabata-Pendias A (2001) Elements of group V. In: Trace elements in soils and plants. 3rd edition. CRC press. London, pp. 225-232.

Leigh RA, Wyn-Jones RG (1984) A hypothesis relating critical potassium concentrations for growth to the distribution and functions of this ion in the plant cell. *The New Phytologist*. 97, 1-13.

Lepp NW (1981) Effect of heavy metals pollution on plants. In: Effects of trace metal on plant function. Ed. N. W., Lepp. Applied Science Publishers, London, England. 1, 299-342.

Liao XY, Chen TB, Lei M, Huang ZC, Xiao XY, An ZZ (2004) Root distributions and elemental accumulations of Chinese brake (*Pteris vittata* L.) from As-contaminated soils. *Plant and Soil*. 261, 109-116.

Mandal BK, Suzuki KT (2002) Arsenic round the world: A review. *Talanta*. 58, 201-235.

Marin AR, Pezeshki SR, Masscheleyn PH, Choi HS (1993) Effect of dimethyl arsenic acid (DMAA) on growth, tissue arsenic, and photosynthesis of rice plants. *Journal of Plant Nutrition*. 16(5), 865-880.

Marschner H (1998) Mineral nutrition of higher plants. Academic Press, London, England.

Meharg AA, Rahman MM (2003) Arsenic contamination of Bangladesh paddy field soils: implications for rice contribution to arsenic consumption. *Environmental Science and Technology*. 37, 229-234.

Mengel K, Kirkby EA (2001) Principles of plant nutrition. 5th edition, Kluwer.

Piper CS (1942) Soil and plant analysis. Hassell Press, Adelaide, Australia.

Robson AD, Hartley RD, Jarvis SC (1981) Effect of copper deficiency on phenolic and other constituents of wheat (Triticum aestivum cv. Sappo) cell walls. *The New Phytologist*. 89, 361-371.

Robson AD, Reuter DJ (1981) Diagnosis of copper deficiency and toxicity. In: Copper in soils and plants. Eds. J. F., Loneragan; A. D., Robson; and R. D., Graham. Academic Press, London. pp. 287-312.

Sachs RM, Michael JL (1971) Comparative phytotoxicity among four arsenical herbicides. *Weed Science*. 19, 558-564.

Sauerbeck DG (1982) Which heavy metal concentrations in plants should not be exceeded in order to avoid detrimental effects on their growth. *Landw Forsch Sonderh*. 39, 108-129.

Shaibur MR, Amin MS, Kawai S (2007) Effect of potassium chloride on growth and accumulation of metal micronutrients in rice seedlings grown hydroponically. *Khulna University Studies, Bangladesh*. 8(2), 245-252.

Shaibur MR, Islam T, Amin MS, Imamul Huq SM, Kawai S (2008) Effect of aeration on arsenic and its subsequent effects on growth and macroelements of rice. *Khulna University Studies, Bangladesh*. 9(2), 291-302.

Shaibur MR, Islam T, Kawai S (2009) Response of leafy vegetable Kalmi (water spinach; *Ipomoea aquatica* L.) at elevated concentrations of arsenic in hydroponic culture. *Water, Air and Soil Pollution*. 202, 289-300.

Shaibur MR, Kawai S (2009) Effect of arsenic on visible symptom and arsenic concentration in hydroponic Japanese mustard spinach. *Environmental and Experimental Botany*. 67, 65-70.

Shaibur MR, Kawai S (2010) Effect of arsenic on nutritional composition of Japanese mustard spinach: An ill effect of arsenic on nutritional quality of a green leafy vegetable. *Nature and Science*. 8(8), 186-194.

Shaibur MR, Kitajima N, Sugawara R, Kondo T, Imamul Huq SM, Kawai S (2006) Physiological and mineralogical properties of arsenic-induced chlorosis in rice seedlings grown hydroponically. *Soil Science and Plant Nutrition*. 52(6), 691-700.

Shaibur MR, Kawai S (2011a) Arsenic toxicity in Akitakomachi rice in presence of Fe^{3+}-citrate. *Advances in Environmental Biology*. 5(6), 1411-1422.

Shaibur MR, Kawai S (2011b) Arsenic toxicity in Akitakomachi rice in presence of Fe^{3+}-EDTA. *Bangladesh Journal of Agricultural Research*. 36(4), 553-562.

Shaibur MR, Sera K, Kawai S (2012) Compositions of xylem fluid of arsenic stressed barley seedlings: A measurement with PIXE system and HPLC. *Water, Air and Soil Pollution,* 223(6), 3085-3092.

Thiel H, Finck A (1973) Ermittlung von grenzwerten optimaler kupfer-Versorgung für hafer und sommergerste. *Z. Pflanzenernähr. Bodenk.* 134, 107-125.

Tu C, Ma LQ, Bondada B (2002) Plant and environment interactions: Arsenic accumulation in the hyperaccumulator Chinese brake and its utilization potential for phytoremediator. *Journal of Environmental Quality*. 31, 1671-1675.

Wallace A, Mueller RT, Wood RA (1980) Arsenic phytotoxicity and interactions in bush bean plants grown in solution culture. *Journal of Plant Nutrition*. 2(1&2), 111-113.

Wheeler RM, Mackowiak CL, Sager JC, Yorio NC, Knott W (1994) Growth and gas exchange by lettuce stands in a closed, controlled environment. *Journal of the American Society for Horticultural Science.* 119, 610-615.